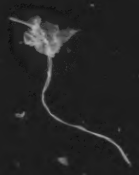
National Defence
Défense nationale



DEFENCE AND CIVIL INSTITUTE OF ENVIRONMENTAL MEDICINE

Canada

June 1989

DCIEM No. 89-RR-28

UNCLASSIFIED

THE RELATIONSHIP BETWEEN SUBJECTIVE AND OBJECTIVE MEASURES OF SIMULATOR-INDUCED ATAXIA

L. Kantor
L.E. Magee
K.M. Hamilton

Defence and Civil Institute of Environmental Medicine
1133 Sheppard Avenue West
P.O. Box 2000
Downsview, Ontario
M3M 3B9

DEPARTMENT OF NATIONAL DEFENCE - CANADA

89-06193/

Table of Contents

ABSTRACT i

INTRODUCTION 1

METHOD 2

RESULTS 3

DISCUSSION 5

ACKNOWLEDGEMENTS 6

REFERENCES 7

TABLE 9

FIGURES 10

ABSTRACT

Subjective reports of simulator-induced ataxia are difficult to corroborate using objective tests of balance. Two reasons for this are ceiling and practice effects that occur with objective tests of balance. In the present experiment an attempt was made to overcome these problems. Postural control was assessed subjectively following exposure to a general purpose flight simulator and objectively using four balance tests specifically designed to avoid ceiling effects. The experimental design was intended to control for practice. Despite these procedures, subjective reports of disequilibrium following training were verified by only one of the balance tests; the Walk On Rail Eyes Open (WOREO) was reliable in showing loss of postural control. The results suggest that the WOREO should be used as an objective test for studying postural disequilibrium following simulator exposure.

Keywords: Simulator sickness; Ataxia tests; Postural control

INTRODUCTION

Flight simulators are often used to help train the aircrew of modern aircraft but simulator training sometimes leads to unwanted aftereffects commonly called simulator-induced sickness (1,2). Subjective reports of simulator-induced sickness include loss of balance (ataxia), dizziness, nausea, headache, eyestrain, and general discomfort (3). Symptoms of balance loss are particularly worrisome because of their potential to compromise safety following simulator training (4). While the reason flight simulators produce ataxia in some aircrew is not clear most investigators speculate that it is caused by readaptation of the human spatial orientation system to the real world following adaptation to the artificial environment provided by the simulator (5,6).

Paradoxically, subjective reports of ataxia following simulator training are not always confirmed by objective tests of balance (1,7). Two possible reasons for this are ceiling effects, and practice effects associated with repeated test presentation procedures used in simulator sickness research (8,9). Ceiling effects may be overcome by using more difficult tests. Practice effects may be minimized by pretraining subjects or controlled by using two groups of subjects; an experimental group and a control group. Pretraining can be impractical for two reasons. First, it is time-consuming. A recent study found that 18 to 24 repetitions were required for performance to stabilize on a number of objective clinical ataxia tests (8). Second, with pretraining, the behaviours involved in performing the tests could be over-learned, which may cause performance to become resistant to disruptive stimulation (10). While controlling for the effects of practice is less time-consuming and reduces the possibility of over-learning, a major drawback of this approach is that twice as many subjects are required.

The purpose of this study was to investigate the relationship between subjective and objective measures of ataxia by employing performance tests designed to avoid ceiling effects and an experimental design intended to control for practice.

METHOD

Subjects

Twenty-nine military college students awaiting pilot training and nine civilians undergoing screening at the Canadian Forces Aircrew Selection Centre volunteered for this study. Since alcohol affects equilibrium (11), five participants were excluded because they reported drinking alcohol less than 12 hours before testing. The remaining subjects (n=33) had a mean age of 21.6 years (range 19-27). None reported any balance problems before the study began. Subjects were randomly assigned to a control (16 males) or experimental group (16 males and 1 female).

Apparatus

The flight simulator used in this study was the Canadian Automated Pilot Selection System (CAPSS). This simulator was designed to gradually teach aircrew candidates the skills required to "fly" a circuit by instruments. This system is a Singer-Link general aviation trainer instrumented to teach basic instrument flight and to record student progress automatically. The cockpit of a single engine light aircraft is simulated. The major components of this simulator include the following: active instrumentation (e.g., altimeter, tachometer, throttle), a monochromatic visual display that plots a "plan view" of the pilot's flight path in real-time and a three-degree-of-freedom motion platform. The motion platform has the following characteristics: pitch of 16^0 nose up and 8^0 nose down, producing a cockpit indicator reading of 48^0 nose up and 24^0 nose down; roll of 12.5^0 left or right bank, producing a cockpit indicator reading of $\pm 75^0$; and yaw of 360^0, producing corresponding heading changes.

Two static tests of balance, the Sharpened Romberg (SR) and the Stand on One Leg Eyes Closed (SOLEC) as well as two dynamic tests, the Walk On Line Eyes Closed (WOLEC) and the Walk On Rail Eyes Open (WOREO) were used as objective measures of ataxia. These tests were specifically designed to avoid ceiling effects. The procedures

and scoring methods are described elsewhere (8,12). A simulator sickness questionnaire was used to assess subjective ataxia (13). This questionnaire required subjects to indicate the presence and severity of 28 symptoms typical of simulator sickness, using a four-point scale.

Procedures

On the first day of the CAPSS training program members of the control group were tested individually on each of the four ataxia tests before and after a 70 min rest period. This rest period is equivalent in duration to the simulator exposure experienced by the experimental group. The tests were administered in a random order for each subject. Following the second administration of the balance tests, each subject responded to the symptom questionnaire.

Subjects in the experimental group were tested individually on the fourth day of training immediately before and after the CAPSS session in a manner similar to the control group. The fourth day of training was the first opportunity students had to combine the skills they had acquired over the previous three days in order to complete circuits. Three consecutive circuits were required with standard rate altitude changes and standard rate left turns. This exercise lasted approximately 70 min.

RESULTS

Table I provides a list of symptoms and a summary of the responses to the symptom questionnaire. Stepwise discriminant analysis identified four items which reliably ($F(4, 26) = 8.77$, $p<0.05$) differentiated the control and experimental groups in terms of the frequency with which they reported particular symptoms. 'Walking straight takes more effort than usual' (item #3), 'energy drain' (item #28), and 'sensations of motion' (item #16) were reported more frequently by the experimental group than by the control group, while 'lack of interest' (item #15) was reported more frequently by the control group. Since two items reported more frequently by the experimental group (#3 and

#16) appear to reflect loss of balance, there is reason to believe that the simulator produced reliable subjective sensations of ataxia. Of 17 aircrew candidates exposed to the CAPSS, 13 reported the presence of one or both of these items, whereas this was the case for only 3 of the 16 candidates in the control group.

Figure 1 summarizes pre- and post-test performance for the control and experimental groups on each of the four ataxia tests. Based on the control group, test-retest reliabilities were 0.88 for the SR, 0.83 for the SOLEC, 0.38 for the WOLEC and 0.69 for the WOREO. Inspection of Figure 1a shows that both groups gained slightly in the mean amount of time they could maintain the SR. This suggests a general improvement in performance. However, repeated measures analysis of variance revealed neither a group by session interaction nor main effects due to session or group.

The results shown in Figure 1b also suggest a general improvement in performance with repeated testing on the SOLEC. Both groups were able to stand on one leg longer, on average, during the second test session. This observation was confirmed by an analysis of variance which revealed a reliable session effect ($F(1, 31) = 7.82$, $p<0.009$) in the absence of a main group effect or an interaction between session and group.

An inspection of Figure 1c shows a similar pattern for the WOLEC results. Both groups demonstrated a mean improvement in performance with repeated testing by adhering more closely to the centre line in their second session. Analysis of variance revealed this effect to be reliable ($F(1, 31) = 15.79$, $p<0.0004$) in the absence of an interaction between session and group or a main effect due to group.

In contrast, the pattern of results shown in Figure 1d suggests that the WOREO scores for the control group increased from the pre- to the post-testing session, while scores of the experimental group did not. Analysis of variance indicated that the two groups differed reliably in their response to repeated testing, evidenced by a significant group by session interaction ($F(1, 31) = 5.21$, $p<0.03$).

DISCUSSION

Discriminant analysis of the responses to the subjective questionnaire suggested that simulator-induced ataxia was experienced by many of the aircrew candidates who trained on the CAPSS. However, only one of the four objective tests of balance, the WOREO, reliably differentiated the performances of the experimental and control groups in a manner consistent with the notion that the simulator precipitated observable evidence of ataxia when ceiling effects were avoided and practice effects were experimentally controlled. One possible reason for this finding is that the objective ataxia measures employed in this study may assess different aspects of postural control. This point of view is consistent with the conclusion of Thomley, Kennedy, and Bittner (9). and implies that the CAPSS may affect dynamic postural control processes specific to the WOREO. Although performances on the SR and SOLEC were found to be more reliable they were not as sensitive as the WOREO to simulator exposure; the results of this study suggest that it would be prudent to include the WOREO when developing a test battery for studying simulator induced ataxia.

ACKNOWLEDGEMENTS

The authors express their gratitude to Major Pomerleau, Sergeant Obirek, Sergeant Perry and the personnel at the Aircrew Selection Centre for their support and cooperation. We also thank Dr. David Sweeney, Dr. David Darvill, Dr. Ronald Heslegrave and Dr. Robert Angus for their valuable input.

REFERENCES

1. Kennedy RS, Frank L, McCauley M, Bittner AC Jr, Root RW, Binks T. Simulator sickness: Reaction to a transformed perceptual world. VI. Preliminary site surveys. Aerospace Medical Symposium on Motion sickness: Mechanisms, Prevention and Treatment. AGARD-CP-372. Springfield, VA: NTIS,1984: 34.1-11.

2. McCauley ME ed. Research issues in simulator sickness. Washington, DC: National Academy Press; 1984.

3. Kennedy RS, Berbaum KS, Allgood GO, Lane NE, Lilienthal MG, Blatzley DR. Etiological significance of equipment features and pilot history in simulator sickness. Aerospace Medical Panel Symposium on Motion Cues in Flight Simulation and Simulator Induced Sickness. AGARD-CP-433 Springfield, VA: NTIS,1987: 1.1-22.

4. Kennedy RS, Merkle PJ Jr, Lilienthal MG. A comparison of postural equilibrium effects following exposure to different ground-based flight trainers. SAFE Symposium. Van Nuys, CA, 1985.

5. Fowlkes JE, Kennedy RS, Lilienthal MG. Postural disequilibrium following training flights. Proceedings. 31st Annual Meeting of the Human Factors Society. Santa Monica, CA, 1987: 488-491.

6. Frank L, Kennedy RS, Kellogg RS, McCauley ME. Simulator sickness: A reaction to a transformed perceptual world. I. Scope of the problem. Second Symposium of Aviation Psychology. Columbus, OH, April, 1983.

7. Magee LE, Kantor L, Sweeney DMC. Simulator induced sickness among Hercules aircrew. Aerospace Medical Panel Symposium on Motion Cues in Flight Simulation and Simulator Induced Sickness. AGARD-CP-433. Springfield, VA: NTIS,1987: 5.1-7.

8. Hamilton K, Kantor L, Magee L. An assessment of postural equilibrium tests for examining simulator sickness. Aviat. Space Environ. Med. 1989; 60:246-251.

9. Thomley K, Kennedy RS, Bittner A Jr. Development of postural equilibrium tests for examining environmental effects. Percept. Mot. Skills, 1986; 63: 1160-1167.

10. McAllister DE. The effects of level of learning and of overlearning on proactive and retroactive facilitation and interference. Iowa, IA: Iowa State University, SPEC-DEVCEN 938 1 8, Aug 1950.

11. Fregly AR, Bergstedt M, Graybiel A. Relationships between blood alcohol, positional alcohol nystagmus and postural equilibrium. Quart. J. Studies on Alcohol, 1967; 28: 11-21.

12. Graybiel A, Fregly AR. A new quantitative test battery. Pensacola, Fl: U.S. Naval School of Aviation Medicine and U.S. Naval Aviation Medical Centre 1965; Report No. 107.

13. Magee LE, Tully P. Diagnosis of simulator sickness in the CF-18 WST. Downsview, Ontario, Canada. Defence and Civil Institute of Environmental Medicine 1985; Report No. 86-R-01.

Table I. Frequency of symptom occurrence in four severity categories (1=symptom is just noticeable, 2= symptom is present but mild, 3=symptom is definitely present but not interfering with my activities, 4=symptom is definitely present, I have to concentrate to overcome the symptom) for the control (n=16) and experimental (n=17) groups after the second set of ataxia tests.

Symptom/Reaction	Control (n=16)				Experimental (n=17)				Total (n=33)
	1	2	3	4	1	2	3	4	
1. MOVEMENT OF VISUAL SCENE	2	1			1	1			5
2. SENSITIVITY TO BRIGHT LIGHT		1			7	1			9
3. WALKING STRAIGHT TAKES MORE EFFORT					1		1		2
4. LOSS OF APPETITE	5	3			4	4	3	1	20
5. MENTAL FATIGUE	2	1			4	2	1		10
6. DIFFICULTY MAINTAINING BALANCE	1				2			1	4
7. GENERAL LOSS OF WELL BEING	3	1	1			1	1		7
8. YAWNING	1	1			1				3
9. DIFFICULTY READING	1				1			1	3
10. IRRITABLE					1	1			2
11. VISUAL FLASHBACKS	1								1
12. DIFFICULTY PERCEIVING DEPTH	2								2
13. BURPING	3				4	1	1		9
14. DIFFICULTY CARRYING OUT FINE MOVEMENT	5	1			2				8
15. LACK OF INTEREST	3				9	1			13
16. SENSATIONS OF MOTION	5				5	3	1		14
17. PHYSICAL FATIGUE	3				1	1	1		6
18. FEELING DETACHED	1	1			4	2	1		9
19. STOMACH AWARENESS		1			1		1		3
20. EXCESSIVE SALIVATION	2		1		2	1		1	7
21. HEADACHE					3				3
22. VISUAL ILLUSION OF MOVEMENT	2				4		1		7
23. LEANS	3				2				5
24. DIFFICULTY IN FOCUSING	5	1			6				12
25. EYE STRAIN	3	2			2	2	1		10
26. RESTLESS	4				3				7
27. SENSATIONS OF LIGHT FOOTEDNESS	4	1			6	3	1	1	16
28. ENERGY DRAIN									
TOTAL	61	15	2		76	24	14	5	197

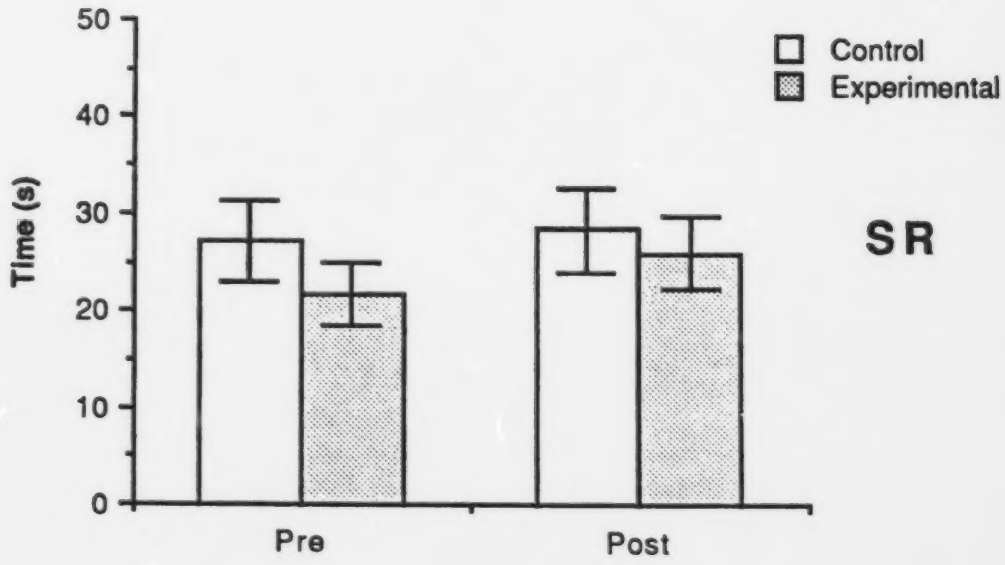


Fig. 1a. Mean standing time for the Sharpened Romberg (SR) in the pre- and post-test conditions for the control (n=16) and experimental (n=17) groups. Bars represent SEMs.

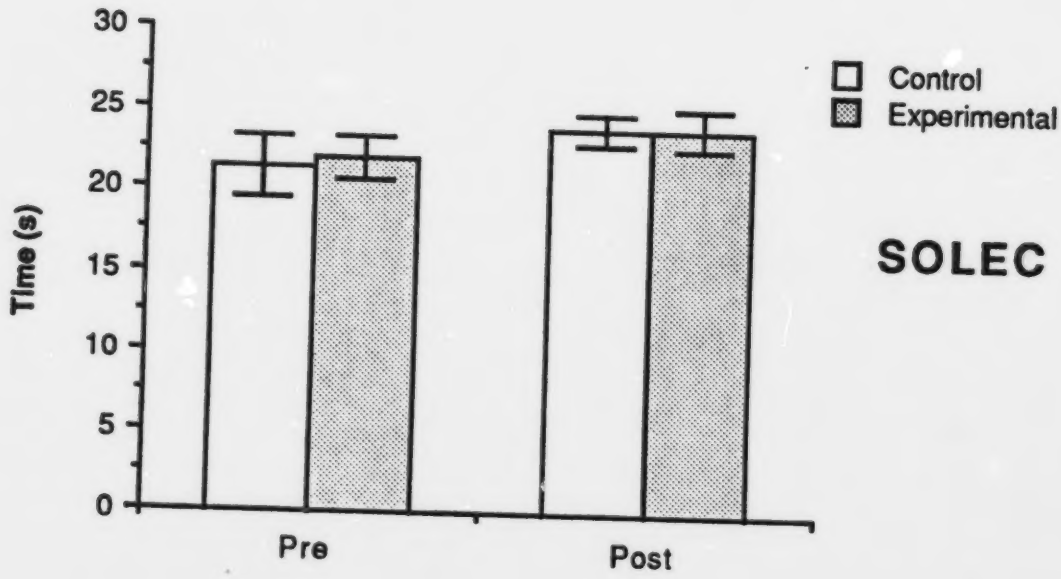


Fig. 1b. Mean standing time for the Stand on One Leg Eyes Closed (SOLEC) in the pre- and post-test conditions for the control (n=16) and experimental (n=17) groups. Bars represent SEMs.

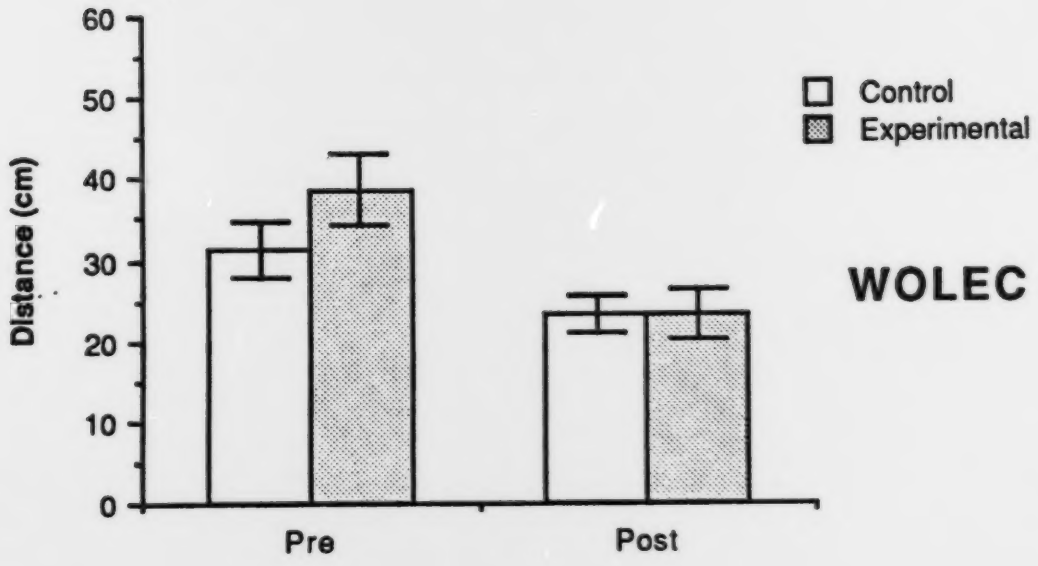


Fig. 1c. Mean distance from centre line for Walk on Line Eyes Closed (WOLEC) in the pre- and post-test conditions for the control (n=16) and experimental (n=17) groups. Bars represent SEMs.

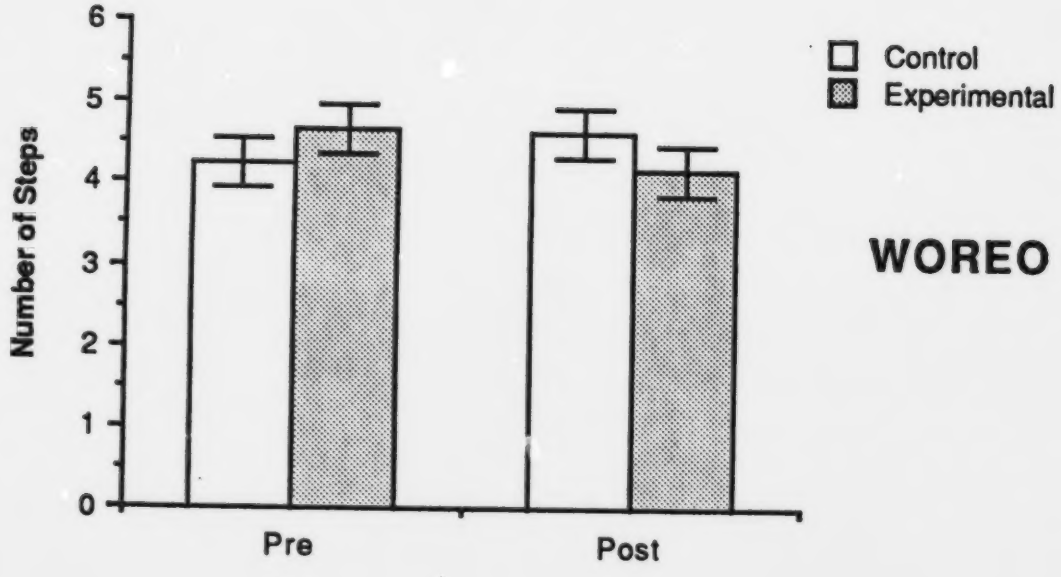


Fig. 1d. Mean number of steps completed for the Walk On Rail Eyes Open (WOREO) in the pre- and post-test conditions for the control (n=16) and experimental (n=17) groups. Bars represent SEMs.

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 8.)

DCIEM
1133 Sheppard Avenue, W., P.O. Box 2000
North York, Ontario M3M 3B9

2. SECURITY CLASSIFICATION (overall security classification of the document. including special warning terms if applicable)

Unclassified

3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C,R or U) in parentheses after the title.)

The relationship between subjective and objective measures of simulation-induced ataxia (U).

4. AUTHORS (Last name, first name, middle initial. If military, show rank, e.g. Doe, Maj. John E.)

Kantor, Lida Magee, Lochlan, E. Hamilton, Kevin, M.

5. DATE OF PUBLICATION (month and year of publication of document)

6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.)

6b. NO. OF REFS (total cited in document)

6. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Research Report

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant)

Proj. No. EB 51CE-12-A

9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)

10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)

10b. OTHER DOCUMENT NOS. (Any other numbers which may be assigned this document either by the originator or by the sponsor)

11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

(X) Unlimited distribution
( ) Distribution limited to defence departments and defence contractors; further distribution only as approved
( ) Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved
( ) Distribution limited to government departments and agencies; further distribution only as approved
( ) Distribution limited to defence departments; further distribution only as approved
( ) Other (please specify):

12. DOCUMENT ANNOUNCEMENT (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, where further distribution (beyond the audience specified in 11) is possible, a wider announcement audience may be selected.)

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both offical languages unless the text is bilingual).

ABSTRACT

Subjective reports of simulator-induced ataxia are difficult to corroborate using objective tests of balance. Two reasons for this are ceiling and practice effects that occur with objective tests of balance. In the present experiment an attempt was made to overcome these problems. Postural control was assessed subjectively following exposure to a general purpose flight simulator and objectively using four balance tests specifically designed to avoid ceiling effects. The experimental design was intended to control for practice. Despite these procedures, subjective reports of disequilibrium following training were verified by only one of the balance tests; the Walk On Rail Eyes Open (WOREO) was reliable in showing loss of postural control. The results suggest that the WOREO should be used as an objective test for studying postural disequilibrium following simulator exposure.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Keywords: Simulator sickness; Ataxia tests; Postural control.